SOIL GAS PROBE

User Manual

For DURRIDGE Hardened Steel Soil Gas Probe
and AMS Stainless Steel Soil Gas Probe

WARNING

The Soil Gas Probe, drive rod and pilot rod are heavy and long pieces of steel. They have sharp, induction hardened points. Take great care in handling them. Before or during use please make sure that the point does not pierce or damage any person, animal or object of value.

Please make sure that no gas, electric, telephone, water, sewage or other service lines or any objects of value lie in the path of pilot rod or probe before driving them into the ground.

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1 Introduction

When measuring radon underground, it is essential to collect samples without exposing them to the outside air. DURRIDGE offers two heavy-duty Soil Gas Probes for this purpose: the Hardened Steel Soil Gas Probe, and the AMS Stainless Steel Soil Gas Probe.

1.1 Hardened Steel Soil Gas Probe

Designed to be simple and effective, the Hardened Steel Soil Gas Probe consists of a hollow steel tube, ½" OD and ¼" ID, with a collar and NPT thread at the top. A ¼" drive rod that slides down the inside of the tube has a heavy cup at the top that clears the NPT thread and bears on the collar round the probe. Also supplied with the probe is a pilot solid steel rod of ⅜" diameter to make a pilot hole for the probe.

1.2 AMS Stainless Steel Soil Gas Probe

The AMS Stainless Steel Soil Gas Probe assembly consists of a 14" (35.6 cm) long probe with pointed tip and a 36" (91.4 cm) long extension, both of which contain rod inserts. Also included is a T-handle and a barbed hose adapter. There are two couplers, one for the T-handle and the other between the extension and the probe. The two rod inserts also have a coupler to join them together. In addition, a water shut-off valve and vacuum gauge assembly, 10 ft (3.05 m) of plastic tubing, an adapter to 5/16" (0.8 cm) ID, and a roll of Teflon tape are provided.

To assemble the AMS Stainless Steel Soil Gas Probe, first wrap Teflon tape around the threads of the 14" probe and one end of the 36" long extension. Join the two together with the coupler provided. Ensure that the threaded joints are airtight. Couple the two rod inserts together and slide them inside the probe. Attach the T-handle adapter to the end of the probe, and then attach the T-handle itself.

2 Soil Gas Probe Placement

To place the Soil Gas Probe, first look for a location well above the water table, where the soil is uniform and generally free of rocks.

Caution: If at any point the probe tip strikes a rock, remove the rod and choose a new location at least ten inches (25 cm) from the earlier spot. In this situation it is better to withdraw the probe and find a new spot rather than to try to force the probe past the rock.

2.1 Hardened Steel Soil Gas Probe Placement

Hammer the pilot rod into the ground to the depth required for sampling. Once the rod has been successfully driven to the required depth, remove the pilot rod to leave a pilot hole in the ground for the probe to penetrate more easily.

With the drive rod positioned inside the probe, hammer the drive rod and probe together into the ground, down the pilot hole, to the depth required. Then remove the drive rod, leaving the probe in the ground.

2.2 AMS Stainless Steel Soil Gas Probe Placement

Place the tip of the Soil Gas Probe at the insertion spot. Hold the probe vertically and apply downward pressure on the T-handle while rotating it slowly in a clockwise direction. Please be careful not to bend the probe, as there is no warranty coverage for misuse.

If the ground is firm it may be difficult to insert the probe to a sufficient depth. DURRIDGE offers a "slide hammer" that can be fitted to the AMS probe instead of the handle. An optional hammer head handle is also available, allowing the use of a mallet on the probe. Either accessory helps to penetrate harder ground. The best solution however may be to use a pilot rod, made of regular steel. A solid steel rod, 0.5” (1.5 cm) diameter and 8” (20 cm) longer than the required probe depth is optimal. Ask a machine shop to machine a sharp tip at one end of the rod and if they can harden the tip so much the better. Two large self-grip wrenches can serve as handles to pull the rod out of the ground.

At the point where you wish to insert the probe, first hammer the pilot rod down to the desired depth, then pull it out and insert the probe. It should go in without too much difficulty. Once in place, the depth of insertion may be calculated by measuring the height of the T-handle above the ground and subtracting that height from the overall length of the probe.

3 Connection to the RAD7

To prevent fresh air from leaking down the outside of the probe, thoroughly tamp down the ground around the probe, or better, pour some Plaster of Paris around the probe and down into the hole around the probe, to seal it in. Leakage of fresh air into the sample acquisition path or down the outside of the probe to the sampling point can be a major source of error in the measurement.

3.1 Hardened Steel Soil Gas Probe Connection

There are two alternative methods of connecting the Hardened Steel Soil Gas Probe to the RAD7. Either push the plug-in hose connector into the probe, or screw on the NPT hose connector.

With the plug-in connector make sure the O-rings are clean and not damaged and that it is a tight, push fit into the probe. For the NPT connector, tightly wrap the NPT thread on the probe with two or three layers of teflon tape. Apply the tape clockwise looking from above - that is in the same direction as the adapter when it is screwed on. Screw on the hose adapter (or the water shut-off valve). Make sure it is good and tight. If there is a leak at this connection, ambient air will be sucked into the tubing to dilute the soil gas, thus reducing the radon concentration in the air sample delivered to the RAD7.

3.2 AMS Stainless Steel Soil Gas Probe Connection

To connect the AMS Stainless Steel Soil Gas Probe to the RAD7, first remove the T-handle and T-handle adapter. If necessary, a pipe wrench may be used to hold the probe. Care should be taken to avoid damage to the tube and to the threads. Remove the rod inserts. Wrap Teflon tape around the thread on the probe and screw on the water shut-off valve and vacuum gauge assembly. Make sure the joint is tight and airtight. The pipe wrench may be used to hold the probe during this process.

3.3 Tubing Connections

Attach the supplied plastic tubing to the hose connector. The other end of the tubing is then connected to the laboratory drying unit. (Note that this connection should go to the upstream connection on the drying unit; that is the one closest to the screw cap.) If a DRYSTIK is used, it should be inserted between the probe and the drying unit.

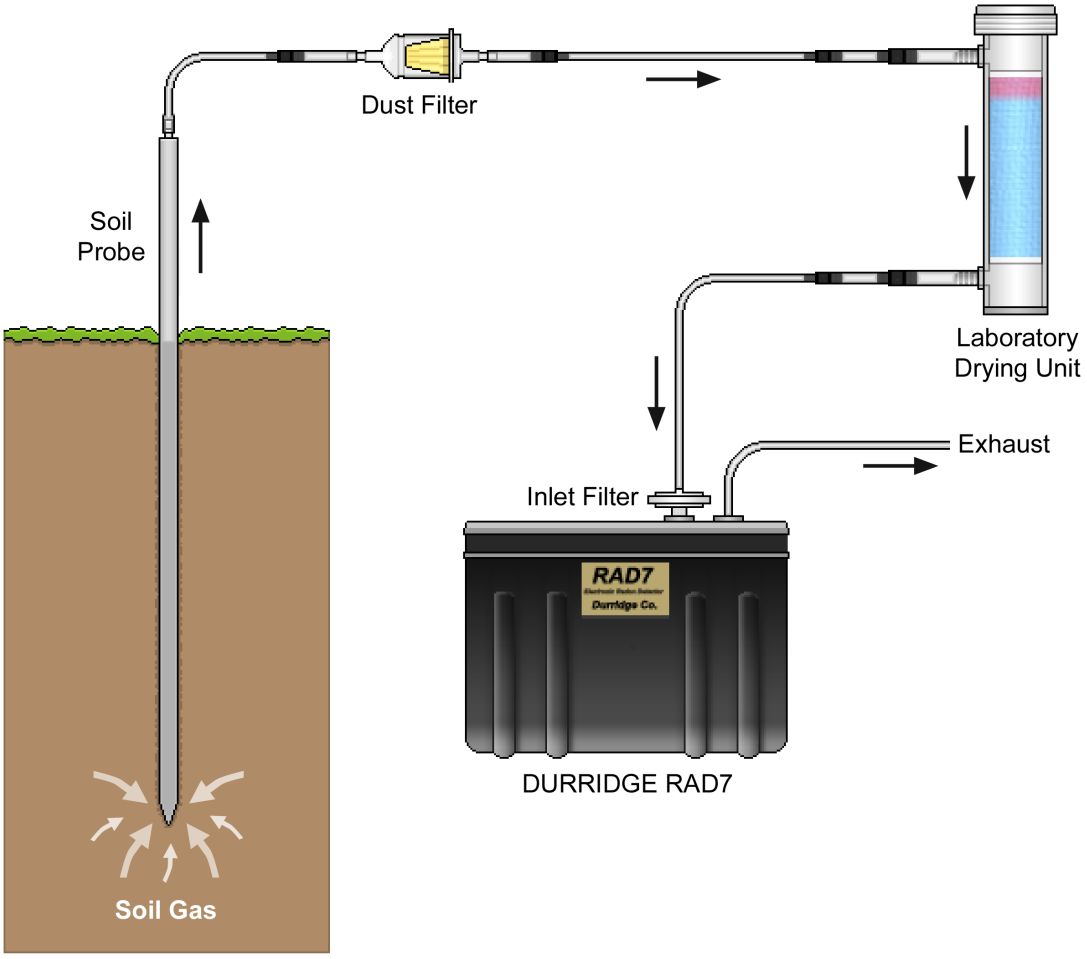


Figure 1 Soil Gas Probe standard configuration

4 Measurement

There are three modes of measurement. One is by obtaining a sample in GRAB mode; another by continuous monitoring using the standard protocol; and the third by operating the RAD7 in THORON mode, with the pump running continuously.

Before starting any measurement, make sure the RAD7 memory and run number are not full. (Press `Data, Free [ENTER]`) and read the number of free cycles - it should be more than 100, (Then press `Data, Read [ENTER]`) and see the run number of the last run - it should be less than 90. If the space or available run numbers are too few, download the data from the RAD7 to a computer and then erase the RAD7 memory (Press `Data, Erase, Yes [ENTER]`).

4.1 GRAB Protocol

For GRAB protocol, it is necessary first to purge the RAD7 for ten minutes or more with dry, fresh air, before connecting the probe.

With the probe disconnected but the drying unit hooked up to the RAD7 start purging (`Test, Purge, [ENTER]`). After at least five minutes push `[Menu]` (to stop the purge). With the printer switched off, put the RAD7 in SNIFF protocol (`Setup, Protocol, Sniff [ENTER]`) and start a reading (`Test, Start`). Go to the third status window (`Menu, Enter, Enter, Rt. Arrow, Rt. Arrow`) and observe the relative humidity in the top righthand corner. Let the RAD7 continue sniffing until the relative humidity drops below 6%.

If the RAD7 was previously used to measure a high radon concentration, it would be prudent also to measure the count rate in window A while the Sniff reading was continuing. Go to the fifth status window (from the third, just `Rt. Arrow, Rt. Arrow`). The lefthand number is the count rate. Typically, 0.25 cpm would be equivalent to a radon concentration of 1 pCi/L, or about 40 Bq/m3. Soil gas is seldom less than 100 pCi/L, so if the count rate in window A has dropped to below 0.5 cpm and the humidity to below 6%, the RAD7 is ready to make the next GRAB protocol reading.

Set the protocol to “Grab” (`Setup, Protocol, Grab [ENTER]`) then turn off the RAD7. Connect the tubing to the probe. Switch on the printer, switch on the RAD7 and let the printer print out a header for this measurement. Check the header to make sure the setup is what is required. Go to `Test Start` and push `[ENTER]` to start the measurement. The RAD7 pump will run for five minutes. The instrument will wait another five minutes and then count for four five-minute cycles. At the end of the half-hour period, the RAD7 will print out a summary of the measurement, including an average radon concentration in the soil gas from the four 5-minute cycle

measurements. This method gives a quick (half-hour) reading and uses the least amount of soil gas. The accuracy will depend on the radon concentration, and would typically be better than +/- 10%.

After the five minutes pumping at the start of the GRAB protocol, the RAD7 may be disconnected from the probe and everything moved to a new site for the next measurement while the RAD7 continues to analyze the grab sample just taken, which will still be in the measurement chamber. After completion of the analysis it is necessary to purge the RAD7 again in preparation for the next sample.

If necessary, the soil gas sample can be pumped out of the ground by a sampling pump, and fed to a Tedlar sample bag for later analysis by the RAD7. With that methodology, care should be taken to ensure that the sample is truly soil gas from the sampling point, and that there is at least 5 litres of soil gas sample in the bag. When analysis is made later, with the RAD7, care should be taken that the RAD7 is first purged thoroughly, so that the relative humidity inside the instrument drops below 6%. Then the bag should be connected to the drying unit and a grab sample protocol measurement started. The result should be corrected for the decay of radon in the sample during the period from acquisition to analysis.

Please note it is impossible to measure thoron concentration with a grab sample because all the thoron will decay away before the measurement is completed.

4.2 Continuous Monitoring

Continuous monitoring is a simple method of measuring the soil gas radon concentration and provides time resolution in the event that the weather or barometric pressure is changing. The setup is as above, but the RAD7 preset protocol may be set to `[Weeks]`. It is still desirable to purge the RAD7 before starting the measurement, but the continuous monitoring process will itself serve to purge the instrument and dry it out. In this protocol, once the relative humidity drops below 10%, the RAD7 will pump for the first five minutes of every two-hour cycle, and then for only one minute in every five.

There will be a reading after every two-hour cycle, though the first reading will be slightly (5%) low because the 218-Po decay rate in the detector takes more than 10 minutes to reach equilibrium with the radon concentration in the measurement chamber. There will be a reading printed out and stored in the RAD7 memory every two hours. The accuracy of the readings will be +/-5% for the typical high radon concentrations found in soil gas.

This method will draw from the sampling point a volume of soil gas equal to the flow rate of the pump (L/min) times 28 minutes, in every two-hour cycle. (Five minutes at the start and then one minute in every five for the rest of the cycle.) In a typical

porous soil the pump flow rate may be around 0.5 L/min. So the soil gas extraction rate will be around 14 litres every two hours. Depending on the soil porosity, this would come from a sphere around the sampling point of around 8" (20 cm) radius. For this protocol, therefore, it is necessary that the penetration depth be much more than the 20 cm radius of the first sample volume. A depth of around 3 ft (1 m) or more, would be sufficient in typical soil to permit continuous readings, at 2-hour cycles, indefinitely without diluting the sample with ambient air, provided no air can leak down the outside of the probe. See Figures 2, 3, and 4, below.

The cycle time can be changed as required. Longer cycle times would use less memory and take slightly less soil gas per hour out of the ground. Shorter cycle times would give higher time resolution but require deeper penetration to avoid dilution with ambient air filtering down through the soil to the sampling point in less than three weeks.

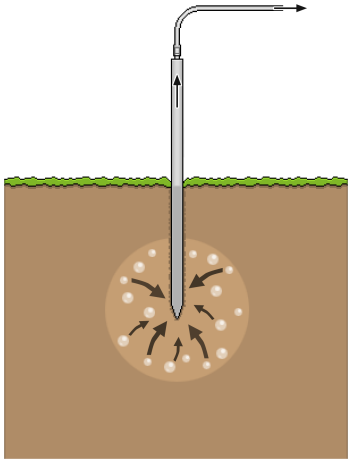


Figure 2 Soil gas is drawn upwards. The spherical region from which the gas is being pumped expands.

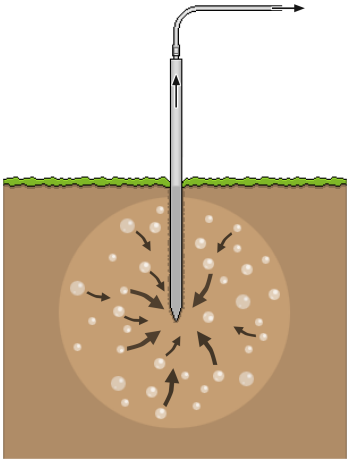


Figure 3 The sphere should not expand enough to touch the surface during the test.

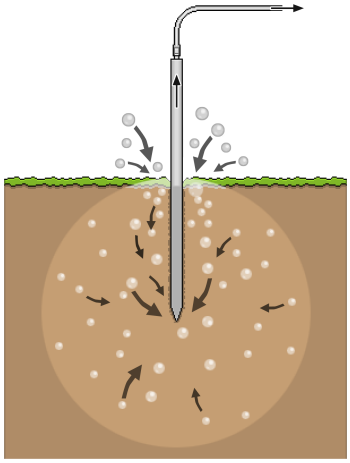


Figure 4 Unwanted Result: Sphere radius exceeds probe depth. Fresh air diffusion occurs.

4.3 Thoron Protocol

Thoron protocol uses 5-minute cycles and prints out both the radon and thoron concentrations at the end of every cycle. However, thoron has a short half-life (one minute) so the pump has to run continuously. For radon the first two cycles should be ignored while the radon reading reaches equilibrium. Thereafter, there will be a reading every five minutes. The print format should be set to [SHORT] to save paper. The thoron reading will be valid for all except the first cycle.

Because of the short thoron half life, some estimate of sample acquisition time is needed if the thoron readings are to be properly interpreted. During acquisition, a flow meter may be connected to the RAD7 outlet. This will show how fast the air is flowing from the sampling point. An estimate of the sample acquisition volume will then allow a calculation of the time delay between sampling and measuring. Call the RAD7 one litre, and the laboratory drying unit one litre. The soil gas probe has a volume of around 150 ml while about 10 ft of 3/16" tubing has another 50 ml for a total of 200ml. The total acquisition delay, then, will be 2.2 litres divided by the flow rate. If that is 0.5 L/min, the delay will be 4.4 minutes. The thoron sensitivity stored in the RAD7 anticipates an acquisition delay of about 1.4 minutes, so the extra delay in this application will be about 3 minutes. During that time, the thoron will decay to about 0.125 of its original concentration, so the thoron reading should be multiplied by 8 to give the thoron concentration at the sampling point.

The final value of the thoron concentration has large uncertainties and the absolute accuracy is probably no better than +100/-50 %. For a soil gas radon concentration of 200 pCi/L (8,000 Bq/m3) the 5-min radon readings however, after the second 5-minute cycle, will have a precision of +/-10 % (95% confidence interval). Higher radon concentrations in the soil will improve the accuracy of the short term readings.

Averaging several readings over a longer period than five minutes will also give a more precise measurement.

One disadvantage of the thoron and sniff protocols is that the pump runs continuously, so that much soil gas is drawn from the sampling point. Compared with 'Weeks' protocol, sniff protocol will draw nearly five times as much gas per hour. This means that the sphere of gas taken from the sampling point will be 1.7 times the radius of the sampling sphere for 'Weeks' protocol in the same total time. So, after a while, ambient air may filter down through the soil to the sampling point before its radon can reach equilibrium with the surrounding radium 226. This may thus dilute the radon concentration. On the other hand, thoron has such a short half life (less than 1 minute) that if the sampling point is deeper than 2 ft (25 cm) the thoron in any air filtering down from the surface will have more than sufficient time to reach equilibrium with the radium 224 in the soil. So, with a sampling point 2 ft or more below the surface, the thoron concentration can be monitored indefinitely, even as the radon readings start to drop due to dilution with fresh air from the surface.

5 Soil Gas Monitoring with DRYSTIK

5.1 Overview of Soil Gas Monitoring with DRYSTIK

The Duty Cycle Controller built into the DRYSTIK (except for the ADS-1 model) is ideally suited for the long-term monitoring of radon concentrations in soil gas using a RAD7 and soil gas probe. The Duty Cycle Controller enables the average flow rate to be reduced to prevent fresh air from diffusing down through the soil to the sampling point. With the Duty Cycle set appropriately, continuous monitoring of soil gas from one sample point may be performed indefinitely. The maximum permissible flow rate depends on the porosity of the soil and the depth of the probe.

The half life of radon is 3.8 days. The air sample may be considered to be drawn from a sphere centered on the sampling point (see Figures 2, 3, and 4 in Section 4.2). If the sphere takes two weeks to grow before it just touches the ground surface, then it takes two weeks for air to filter down to the sampling point. We may then accept that the air at the sampling point continues to stay very close to equilibrium with the radium in the soil.

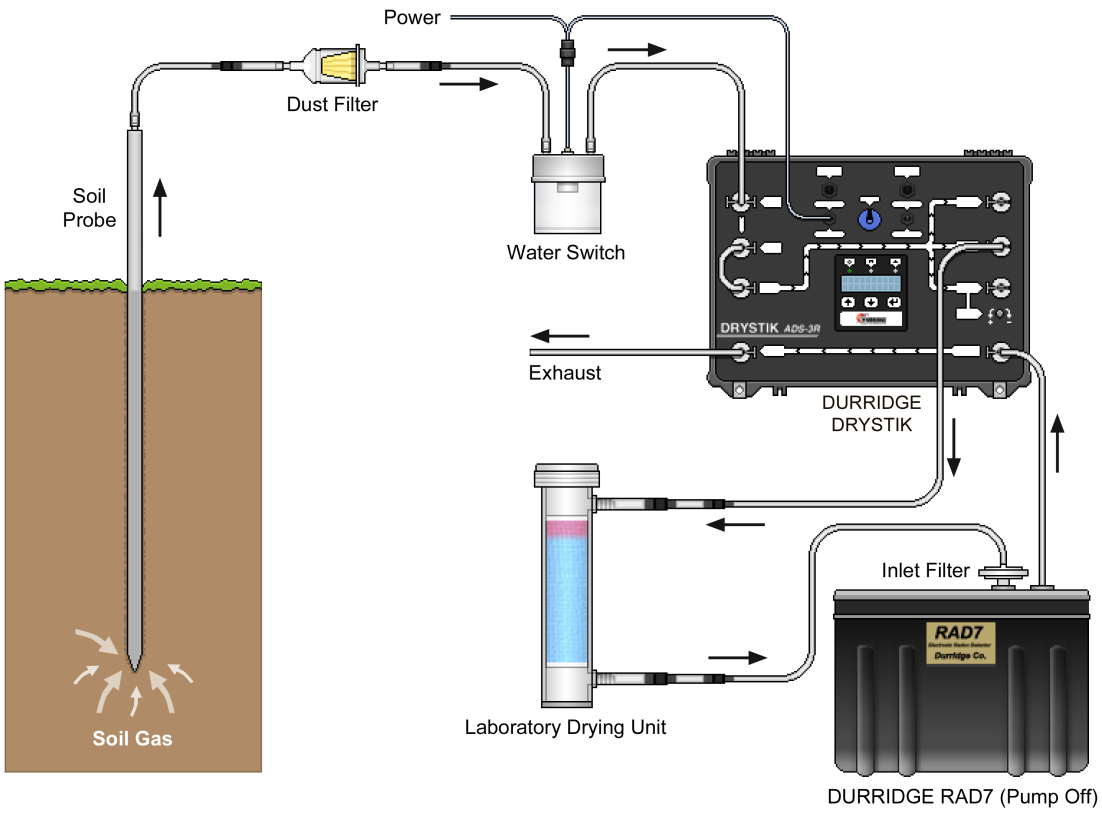


Figure 5 Soil Gas Probe configuration with DRYSTIK

For a probe depth of D cm, the maximum sphere volume will be 4πD3/3,000 litres. If the porosity of the soil is 50%, the corresponding air volume will be 2πD3/3,000. Two weeks is about 20,000 minutes. So the average flow rate must be less than 2πD3/ 60,000,000 litre/min. If we allow that 2π is close to 6, the rate must be less than D3 * 10-7 litre/min where D is the probe depth in cm.

Maximum flow rate, F, is roughly given by:

F = D3 / 107 litre/min
where D is the probe depth in cm.

If, for example, D is about two feet, or 61cm, the maximum flow rate to meet this criterion for continuous sampling will be 0.022 L/min. Uncertainties in the porosity and other assumptions may make it advisable, for this depth, to keep the flow rate less than 0.01 L/ min.

Typically, the ON flow rate of the DRYSTIK is set to about 0.2 L/min to match the average flow rate of a RAD7 where the pump, pumping at 1 L/min, runs for one minute in every five. On the DRYSTIK ADS-3 or ADS-3R simply select the desired 'Soil Gas' profile. On the DRYSTIK ADS-2, the Duty Cycle should be set to about 5%, or to an ON time of 60 seconds and an OFF time of 1200 seconds. This produces an average flow rate of 0.01 L/ min from the soil gas probe.

With a probe depth of 61 cm and a porosity of 50%, this setting will enable continuous, indefinite sampling of the soil gas for radon concentration without significant dilution of the sample by fresh air diffusing down from the surface. Increasing the depth by 26%, to 77 cm, will allow double the flow rate, assuming uniform soil porosity down to 2 m or so.

5.2 Minimum Flow Rates

Radon has a half life of 3.8 days. If the air sample takes more than an hour or two to reach the measurement chamber, there may be enough sample loss to call for a sample decay correction. With a laboratory drying unit in the air path, you can assume a sample path volume of about 2 litres, plus more if the probe is so far from the RAD7 that the volume of the tubing becomes significant. If the probe is close to the RAD7 (within about 10m) and the maximum acceptable delay before corrections have to be applied is 2 hours, then the minimum permissible flow rate will be 2L / 120min, or 0.016 L/min. Flow rates lower than this will require a correction factor for radon decay, as discussed below.

5.3 Correcting for Very Low Flow Rates

In the examples above, it may be seen that for a probe depth of 61 cm, to avoid dilution of the air sample after a week or two of sampling, a flow rate of no more than 0.01 L/min is desired, but with this flow rate the sample will lose some radon by radioactive decay during sample acquisition.

One solution to this problem would be to increase the sampling depth to 2 ft 6 inches (77 cm) or more and draw at an average flow rate of 0.02 L/min. This may be obtained with a duty cycle of 10% (for example, an ON time of 3 sec. and an OFF time of 30 sec.) with a flow rate of 0.2 L/min.

Another solution would be to leave the sampling point at 2 ft (61 cm), draw at an average flow rate of 0.02 L/min, taking note of any long-term change in the average after one week of sampling, and then apply a correction for fresh air infiltration to readings after three or four weeks of sampling.

A third solution would be to keep the probe at 2 ft (61 cm) and keep the flow rate at 0.01 L/min. Assuming a sample volume of 2 L, this will cause an acquisition time of around 2/0.01 min = 200 minutes. In 200 minutes, about 2.5% of the radon will have been lost by radioactive decay. A factor of 1.025 may therefore be applied to the reading to correct for the loss.

5.4 Measuring Thoron in Soil Gas with the DRYSTIK

Thoron has a half life of less than a minute. Using the DRYSTIK with a typical configuration will inevitably cause sample acquisition delays far in excess of one minute. Therefore changes are needed for the measurement of thoron.

To measure thoron in soil gas, the DRYSTIK's needle valve should be bypassed and the pump should be set to run continuously. The flow rate will then be close to 1 L/min if the soil is porous.

At a flow rate of 1 L/min, with a Laboratory Drying Unit in the sample path, the sample delay increase over standard thoron protocol will be about 1 minute. Therefore the thoron readings should be multiplied by a factor of 2. If the flow rate is reduced and/or the sample volume is larger, a greater correction factor will be needed.

6 Continuous Long-Term Operation

It has been proposed that continuous monitoring of soil gas for radon may be a useful technique for predicting earthquakes. For this purpose, an array of soil gas probes covering half a square kilometer, say, may be more informative than a single sampling point. Such an array can be monitored with a single RAD7. Fine bore plastic tubes may be run for hundreds of meters from each probe to a centrally located DURRIDGE valve manifold system. The RAD7 may be connected to the manifold and switched from one tube to another under the control of the manifold system micro-controller. Each tube is purged prior to the RAD7 hook-up, so that the soil gas sampled is fresh. One measurement can be made every hour. If each sampling point had to be read six times a day, say, there could be four sampling points monitored by one RAD7.

With a Bluetooth adaptor connected to the RAD7, the controlling PC can be located anywhere. Real-time data is collected by the PC while a back-up set of data is stored in the RAD7. Please see the RAD7 and CAPTURE software manuals for further details.

7 Care and Maintenance

To ensure the longevity of the soil gas probe, avoid hitting rocks with excessive force. Remove all dirt and contaminants from the probe after each use and store the probe components in a dry place. Keeping the probe properly oiled will help to prevent rust from forming.

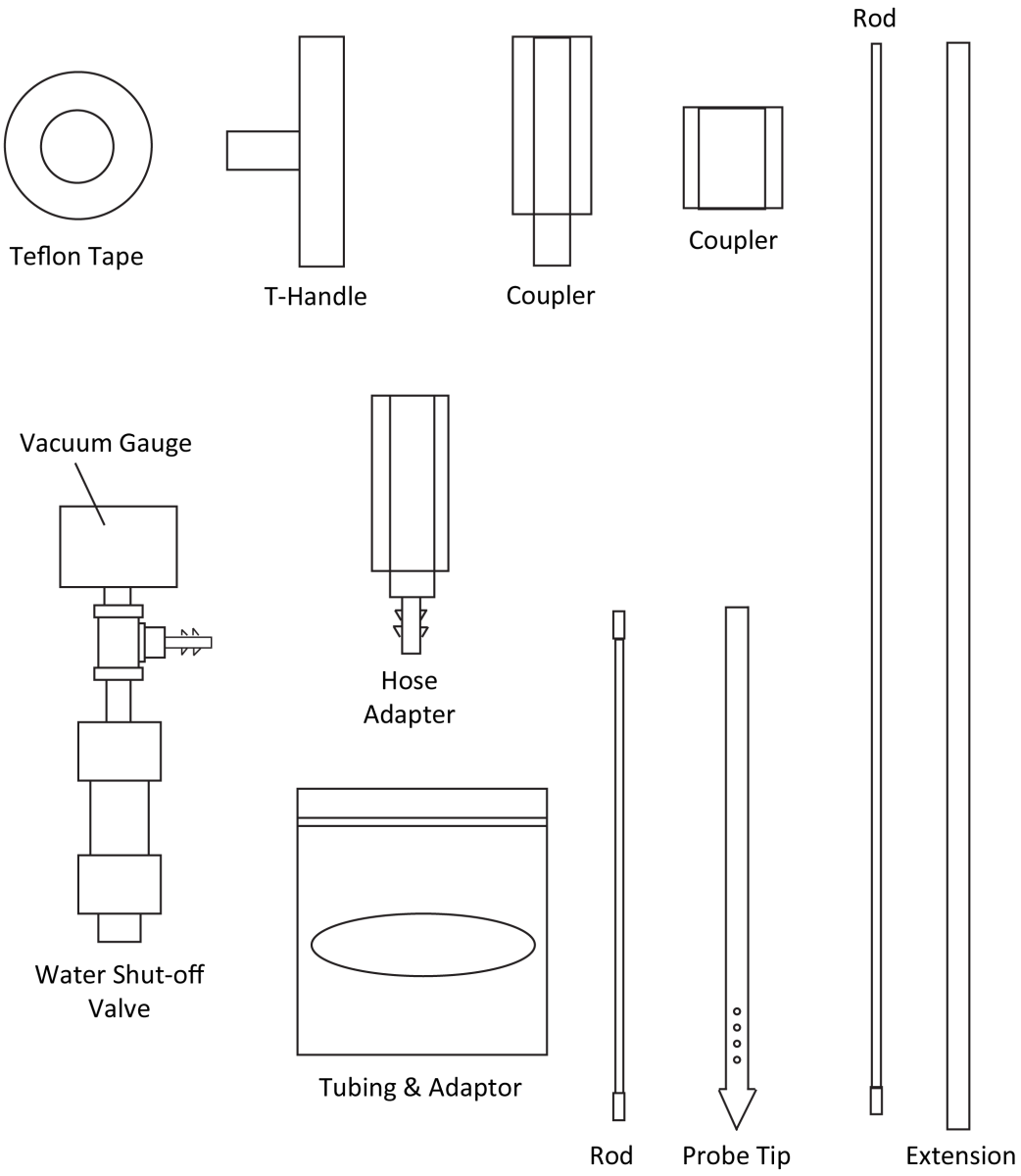
Contact DURRIDGE Company, info@durridge.com, for technical assistance.

8 Specifications and Components

8.1 Soil Gas Probe Specifications Table

	DURRIDGE Hardened Steel Soil Gas Probe	AMS Stainless Steel Soil Gas Probe
Construction	Steel	Stainless Steel
Pilot Rod	Included	Not Included
Vacuum Gauge	Optional	Included
Insertion Method	Hammer into ground	Push into ground (hammer optional)
Removal Method	Self-grip wrenches (not included)	Pull out using included handle
Hose Connectors	Female NPT thread and O-ring	Female hose connector
Maintenance	Clean and oil after use	Basic cleaning recommended
Additional Notes	—	Metal joints may be taped to prevent outside air from entering

8.2 AMS Soil Gas Probe Components


Rod
Teflon Tape
T-Handle
Coupler
Coupler
Vacuum Gauge
Hose
Adapter
Water Shut-off
Valve
Tubing & Adaptor
Rod
Probe Tip
Extension

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